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14. ABSTRACT
UUVs were adapted, equipped with electric and magnetic field sensors, and tested at the South Florida Ocean Test Facility (SFOMF). A larger 3"-diameter ball-shaped electric field sensor was developed and fabricated. Testing of the 3"-diameter ball-shaped sensor at UI showed a noise floor of 1μV/m RMS in the frequency band 0.02-20 Hz. UUV-acquired measurements were conducted at the SFOMF facility April 4-8, and August 15-19 2016. Measured electric and magnetic field compared favorably to predicted fields generated by the known sources in the experiments. Improvements to UUVs enabled them to operate robustly in the ocean environment. Software to monitor and control operation of the UUVs from the surface was developed and implemented in field tests. Development and fabrication of a miniature data acquisition (DAC) system was initiated. Completion of the DAC in subsequent work will enable the fabrication of a stand-alone magnetic and electric field measurement system. The work documented in this final report is a continuation of work performed under ONR Grant N000141410662.

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Configurable UUV Sensor Network II

Final Report
12/12/2017

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ABSTRACT

UUVs were adapted, equipped with electric and magnetic field sensors, and tested at the South Florida Ocean Test Facility (SFOMF). A larger 3"-diameter ball-shaped electric field sensor was developed and fabricated. A pre-amplifier was embedded in the body of the sensor. Testing of the 3"-diameter ball-shaped sensor at UI showed a noise floor of 1μV/m RMS in the frequency band 0.02-20 Hz. UUV-acquired measurements were conducted at the SFOMF facility April 4-8, and August 15-19 2016. Measured electric and magnetic field compared favorably to predicted fields generated by the known sources in the experiments. Improvements to UUVs enabled them to operate robustly in the ocean environment. UUVs have been modified to increase propulsive power, and to navigate in ocean currents. Software to monitor and control operation of the UUVs from the surface was developed and implemented in field tests. Development and fabrication of a miniature data acquisition (DAC) system was initiated. Completion of the DAC in subsequent work will enable the fabrication of a stand-alone magnetic and electric field measurement system that could be used with other UUVs. The work documented in this final report is a continuation of work performed under ONR Grant N000141410662 for the period of performance from September 1, 2016 to August 31, 2017.

LONG-TERM GOALS

The long-term goal of this project was to develop a portable assessment system to evaluate the magnetic and electric field signature of forward deployed ships and submarines. Inexpensive, easily deployable small unmanned underwater vehicles (UUVs) will be equipped with magnetic and electric field measurement systems. These UUVs will then be trained to work together to assess the electro-magnetic signature of a forward deployed ship or submarine.

OBJECTIVES

The objectives of the project are:

- Modify UUVs to permit operation in saltwater environment, equip UUVs with electric field sensors developed at the University of Idaho in collaboration with the Carderock Naval Surface Warfare Center.

- Develop navigation system appropriate for use at SFOMF which includes an extended Kalman Filter for estimating ocean currents during Florida Tests to improve UUV navigation.

- Develop and test UUV system with electric field sensor.

- Develop mathematical models for UUV tracking system and investigate the use of an acoustic tracking system located on the ship whose signature is being measured to determine the positions of the UUVs.

- Improve communication and control system. The AV Commander software along with the associated UUV software needs to be further developed to monitor, communicate, and control the UUVs for signature missions.

APPROACH

A UUV-based survey technology to perform electromagnetic and electric field signature measurements on cooperating naval vessels in an operational environment is being developed. Previous efforts by the University of Idaho (UI) and the Acoustic Research Detachment (ARD) have resulted in a fleet of small UUVs, each equipped with a magnetometer. A magnetometer- and electric field sensor-equipped UUV is shown in Figure 1. These UUVs have been used to perform a magnetic signature measurement on a small surface craft in a fresh-water test facility. Current UUV technology has been developed for operation in an ocean environment with full-scale surface vessels. Adaptions include integration of an electric field sensor onto the UUVs, deploying acoustic navigation components, and performing overall system automation appropriate for testing in an ocean environment. UUV-acquired measurements of the electromagnetic signature of a surface vessel will be compared to predictions of known sources in the experiments, and possibly to separate measurements conducted at SFOMF. Furthermore, system components will be developed that result in a stand-alone measurement system that can be used by other UUVs.

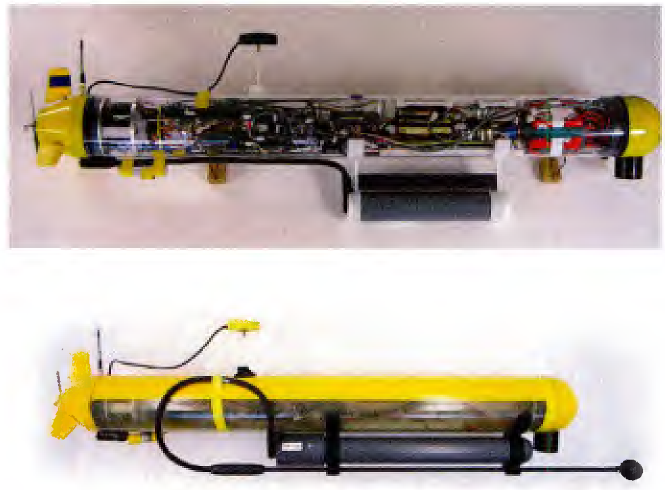

Figure 1. UUV with magnetometer (upper), and electric field sensor (lower).

WORK COMPLETED and RESULTS

Analysis of Magnetic Field Measurements Taken at SFOMF August 15-19, 2016:

During the period August 15-19 2016, AUV-acquired measurements of the magnetic field caused by a controlled source on a moving surface boat were conducted. In the experiments, the surface boat proceeded along a straight path. An AUV simultaneously approached the surface boat in the opposite direction, at a nominal depth of 10 m.

In the Final Report for "Configurable UUV Sensor Network" (N000141410662), submitted in March 2017, analysis of the AUV-acquired measurements was described. An analysis contained in the Final Report for "Configurable UUV Sensor Network" is reproduced here in Figure 1. The lower plot in Figure 1 contains the departure of the measured and predicted total magnetic field. Since then, it has been discovered that there was an error in this analysis, in that the polarity of one of the magnetometers was incorrectly reversed.

The computation of measured magnetic field has since been corrected. A plot of the corrected measured magnetic field, now also including the terrestrial component, corresponding to the same run as contained in Figure 2, is shown in Figure 3. As can be seen, the corrected measured magnetic field did not change significantly. In our opinion, the largest discrepancy is that the measured magnetic field has advanced in time. We believe that this temporal shift is a consequence of navigation accuracy. We are presently working to apply a non-causal analysis to improve the navigation accuracy.

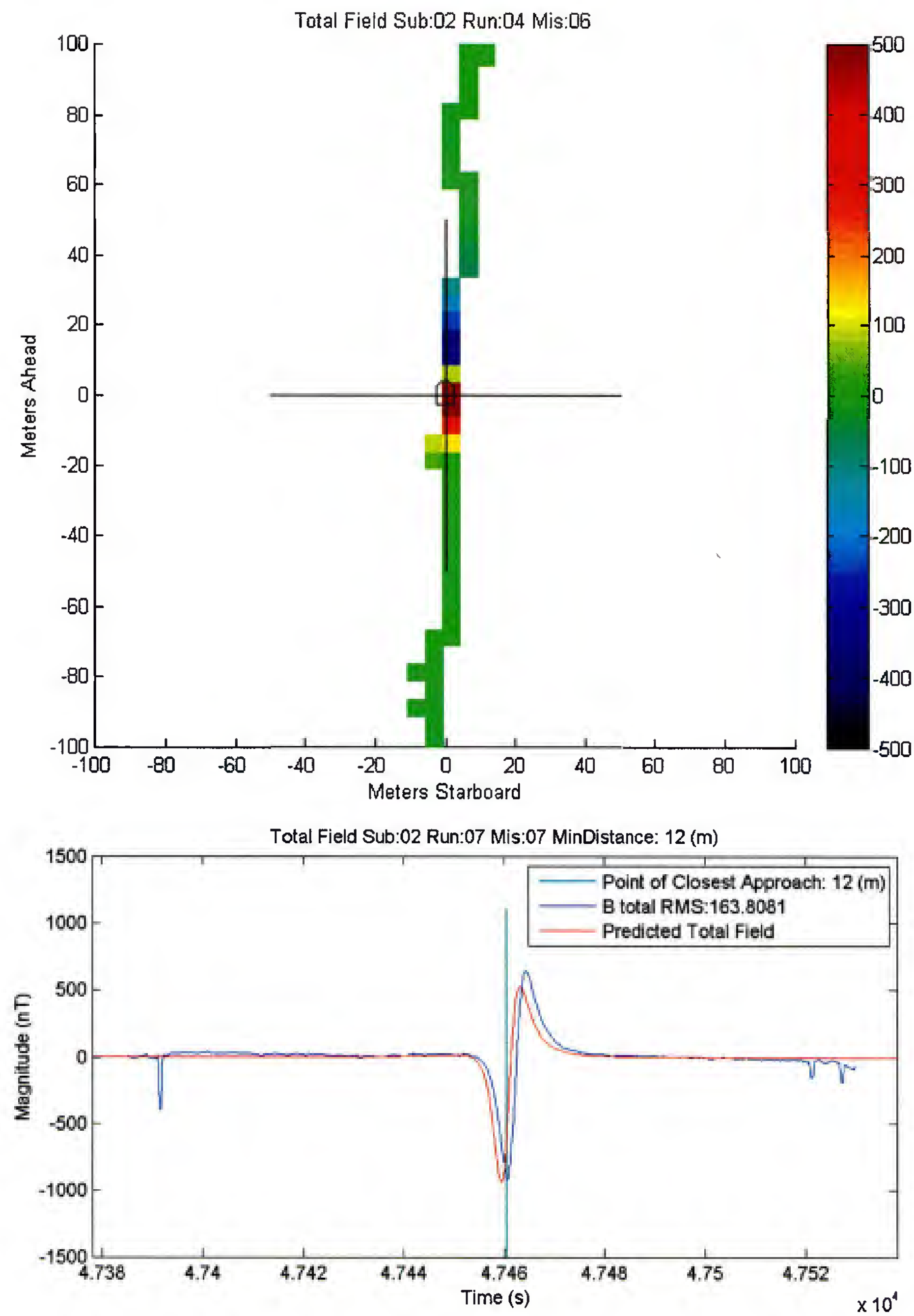

Figure 2. Measurement of known magnetic source on surface boat using magnetometer-equipped UUV. As contained in Final Report for "Configurable UUV Sensor Network", N000141410662.

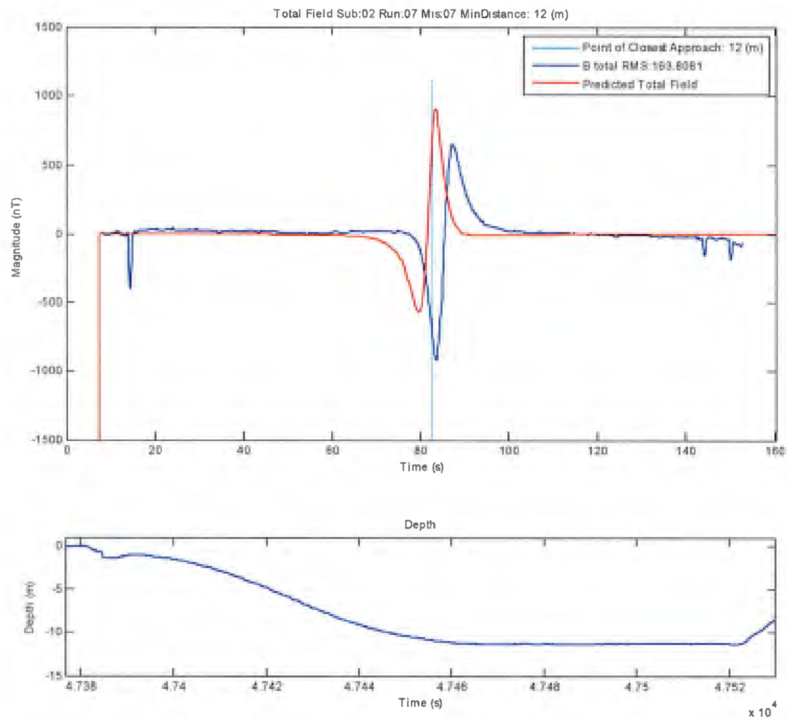

Figure 3. Measurement of known magnetic source on surface boat using magnetometer-equipped UUV. Analysis corrected to include correct polarity for one of the magnetometer output channels.

Submersible Housing for Self-Contained Electric- and Magnetic-Field Measurements:

An objective of the project is to develop and fabricate a self-contained electric- and magnetic-field measurement unit that can be installed on *any* AUV. This unit will contain electric and magnetic field sensors, an inertial measurement unit (IMU), and a digital-data-acquisition system (DAC).

A housing for the self-contained unit has been designed. A rendering of the sensor-housing unit attached to an AUV is shown in Figure 4. The housing is made from three components; a nose-cone, a cylindrical fibre-reinforced polymer tube, and a tail fitting. It is intended that the magnetometer, IMU, and data acquisition unit (DAQ) will reside in the housing.

Upgrades to AUV System Software (AV Commander)

A software package, called AV Commander, is used to control AUV movements from the surface. To improve operation in the ocean environment, several upgrades have been implemented:

We updated the mission planning software to automatically generate the code loaded onto the subs to eliminate copy/paste errors thus increasing reliability. This also has the benefit of reducing the required time for planning and programming the subs. The mission planning software now automatically generates the kml files for display in Google Earth. This allows us to check the waypoints were programmed in correctly, and the kml files are used with AV-Commander to monitor the subs progress/position.

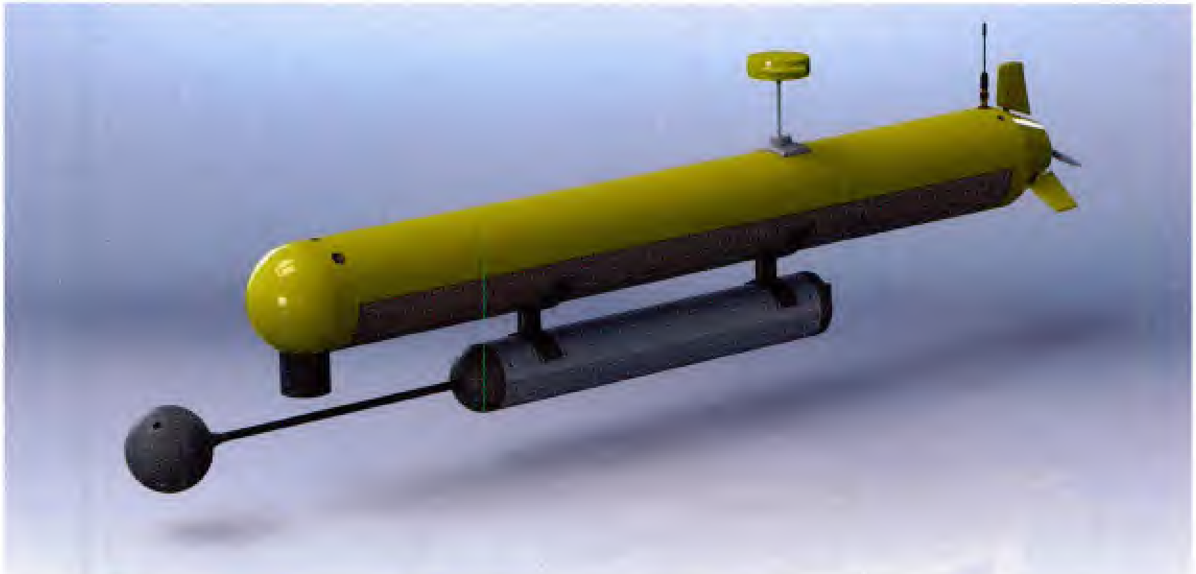

Figure 4. Self-contained sensor housing, rendered as attached to AUV.

Development of Data-Acquisition System (DAQ) for Standalone Sensor

Two boards were developed that employed an Atmel AVR (ATmega32U4) microcontroller to operate a D/A converter (ADS1263 or ADS1299). This microcontroller is widely used and a USB software library is available. Hardware was verified and software testing began. During software testing a large latency, internal to the microcontroller, was identified. Failed attempts were made to fix this problem with software, thus necessitating a new microcontroller. An Atmel ARM (SAM D21 ARM Cortex-M0+Microcontroller) microcontroller was found to have adequate specifications to correct this problem with roughly 12 times theoretical throughput increase.

IMPACT/APPLICATIONS

Currently, ships and submarines are degaussed in a naval shipyard. While onboard systems allow the vessels to compensate for inevitable ship magnetic and electric field changes acquired as a result of deployed transoceanic voyages, the missing piece is an accurate real-time assessment of those changes at their destinations. The portable assessment system being developed in this project would allow the magnetic and electric field signature of a ship to be determined and possibly mitigated anywhere in the world.

RELATED PROJECTS

This task leverages four previous ONR-funded projects, Decentralized Control of Multiple Autonomous Underwater Vehicles (ONR Grant N000140310634), Decentralized Control of Multiple Autonomous Crawlers and Swimmers (ONR Grant N000140310848), Communication and Control for Fleets of Autonomous Underwater Vehicles (ONR Grant N000140410506), and Configurable UUV Sensor Network (ONR Grant N000141410662). In addition, small UUVs fabricated under another related project, Fabrication of a Fleet of Mini-UUVs (ONR Grant N000140410803), were being tested at

Bayview under this project. Another related project is the Cooperative Autonomous Underwater Vehicles Used to Search Large Ocean Areas for Mines (ONR Grant N00014-08-1-0276).

PUBLICATIONS (2016-2017)

*=student

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